TITLE

AERATION SENSING DEVICE

BACKGROUND OF THE INVENTION

The present invention relates generally to an apparatus for detecting gas entrapped in a liquid lubricating system, and more specifically, to an aeration sensing device for detecting gas entrapped in the engine oil of an internal combustion engine.

Engine oil has been used in engine systems to lubricate moving parts such as pistons, piston rods, compression rings, and other engine components to reduce friction and heat build up between the moving parts and an engine block. Contaminants or foreign substances found in the engine oil can inherently damage an engine system. Gas, such as air or combustion products, entrapped in the lubricant can also result in improper or inadequate lubrication of the engine components and can damage engine components including the oil pump.

Vehicle systems utilize various sensors within a vehicle to monitor whether an engine is operating within normal operating parameters. One type of such sensors is an oil pressure sensor that monitors the oil pressure exiting from the oil pump. If the oil pressure goes below or above a predetermined operating range, a warning indicator is displayed to the operator of a vehicle informing the operator of the improper operating condition that is occurring. However, oil pressure sensors are used only for detecting the oil pressure of the engine system, and such sensors are not indicative of aeration caused by gas entrapped in the engine oil. Aeration within the engine oil may not necessarily affect the oil pressure, but the aeration could still cause damage to the engine components. An aeration detection system as described in U.S. 4,599,888 utilizes a rod encased within a cylinder for monitoring the capacitance with oil flowing between the rod and the cylinder wall. However, other impurities or contaminants within the engine oil could change the capacitance. The system in the referenced patent does not differentiate between contaminants in the lubricant causing a capacitance change and aeration in the system causing a capacitance change.

SUMMARY OF THE INVENTION

The present invention concerns a system for detecting aeration in a lubricant which system includes a sensor having a pair of spaced apart concentric rings forming a first capacitor through which the lubricant flows and a capacitor segment forming a second capacitor with the outer ring. The capacitors are connected in a balanced bridge circuit and the second capacitor is constructed to remove gas entrapped in the lubricant present in the second capacitor so that the bridge becomes unbalanced indicating gas entrapped in the lubricant flowing through the first capacitor.

The aeration sensing system comprises: a non-conductive sensor body having opposed first and second ends; a first capacitor positioned within the sensor body and having spaced apart plates forming a first gap; a lubrication flow path formed in the sensor body between the first and second ends and including the first gap; a second capacitor positioned within the sensor body and having spaced apart plates forming a second gap in fluid communication with the lubrication flow path, the second gap being in the form of a dead-end cavity; a bridge circuit having the first and second capacitors connected in associated legs thereof; and a signal generator connected to and generating an input signal at an input of the bridge circuit, the bridge circuit being balanced when non-aerated lubricating fluid is flowing in the lubrication path and being unbalanced when aerated lubricating fluid is flowing in the lubrication path.

The signal generator can be an oscillator and the system includes a demodulator connected to an output of the bridge circuit for generating an output signal. The plates of the first capacitor are first and second conductive rings positioned concentrically in said sensor body and the plates of the second capacitor are the second conductive ring and a conductive segment positioned in the sensor body. The first and second rings and the segment can be formed of copper material and the sensor body can be formed of a plastic phenolic material.

DESCRIPTION OF THE DRAWINGS

The above, as well as other advantages of the present invention, will become readily apparent to those skilled in the art from the following detailed description of a preferred embodiment when considered in the light of the accompanying drawings in which:

Fig. 1 is a side elevation view of an aeration sensing device according to a first preferred embodiment of the present invention in cross section taken along the line 1-1 in Fig. 2;

Fig. 2 is an end view of the aeration sensing device shown in Fig. 1;

Fig. 3 is a perspective view of the first and second capacitance plates shown in Fig. 1;

Fig. 4A is a view similar to Fig. 1 of an aeration sensing device according to a second preferred embodiment of the present invention in cross section taken along the line 4A-4A in Fig. 5;

Fig. 4B is an enlarged cross-sectional view taken along the line 4B-4B in Fig. 5;

Fig. 5 is a view similar to Fig. 2 of the aeration sensing device shown in Figs. 4A and 4B;

Fig. 6 is a perspective view of the first and second capacitance plates shown in Fig. 4A; and

Figure 7 is an electrical diagram of an aeration sensing system incorporating the sensors according to the present invention.

DESCRIPTION OF THE PREFERRED EMBODIMENT

Referring now to the drawings and particularly to Figs. 1 and 2, there is shown an aeration sensing device **10** for detecting gas entrapped in a liquid lubricating system. The aeration sensing device **10** is mounted between a filtration device **14** (e.g. an oil filter) and a filtration device mount **12** (e.g. an engine oil filter mount). The aeration sensing device **10** includes a generally cylindrical sensor body **11** that is produced from a nonconductive material such as plastic phenolic. Alternatively, the sensor body **11** can be made from any other high temperature nonconductive composite material. The filtration device mount **12** has a lubrication outlet circuit or passageway **16** formed therein open to a facing surface **15** of the mount. The circuit **16** allows lubricant to flow from a lubricating area (not shown) to the aeration sensing device **10** and on to the filtration device **14**. A return passageway or lubrication inlet circuit **17** is formed in the mount **12** and is open to the surface **15** for allowing filtered lubricant to return from the filtration device **14** through the sensing device **10** to the lubrication area (not shown). The surface **15** is surrounded by an outwardly extending flange **13**.

The return path includes a tubular conduit **18** having an externally threaded first end **18a** threadably engaged with an internal thread formed in the opening of the inlet circuit **17**. The conduit **18** extends through an axial aperture or central bore **19**, formed in the body **11**, to an externally threaded second end **18b** that threadably engages the filtration device **14**. Although the conduit **18** is shown and described as threadably engaging the mount **12** and the filtration device **14**, other methods of fastening known in the art may be utilized. An internal diameter of the central bore **19** is slightly larger than an outer diameter of the return conduit **18** to allow the aeration sensing device body **11** to slip fit over the conduit and rotate thereabout. The conduit **18** is first threaded into the open end of the inlet circuit **17** and then receives the sensing device **10**. The sensor body **11** has a first end **11a** that abuts the flange **13**. Then the filtration device **14** is threaded onto the second end **18b** of the conduit **18** and rotated to tighten an end **14a** of the filtration device against a sensor body second end **11b** to seal the flange **13** to the surface **11a** and to seal the end **14a** to the surface **11b**. An annular groove **20** can be formed in the surface **11a** to retain an O-ring **21** for better sealing at the abutting end **11a** and the flange **13**. Typically, the filtration device **14** has an annular groove (not shown) formed in the surface **14a** to retain an O-ring (not shown) for better sealing at the abutting ends **11b** and **14a**.

Alternatively, the conduit **18** can be divided for threaded engagement with the corresponding ends of the central aperture **19**. Thus, as oriented in Fig. 1, a left portion of the conduit **18** would threadably engage the aperture **19** at the first end **11a** and a right portion would threadably engage the aperture **19** at the second end **11b**.

A smaller diameter first conductive capacitor ring **22** and a larger diameter second conductive capacitor ring **23** are press fit into the sensor body **11**. Alternatively, the sensor body **11** may be injection molded and the first and second rings **22** and **23** may be overmolded into the sensor body **11**. Both of the first and second rings **22** and **23** are made from a suitable material such as copper tubing and share a common axis with the sensor body **11** and the central aperture **19**. Other types of conductive material may be utilized in place of the copper tubing.

In the preferred embodiment, as best shown in Fig. 3, the first ring **22** includes an axially extending wall formed of a plurality of arc shaped plates or wall segments **24** extending axially along the common axis with adjacent wall segments separated by one

of a plurality of slots or openings **25**. A terminal lug **26** extends radially from the first ring **22**. The second ring **23** is of similar construction to the first ring **22** and has a plurality of arc shaped plates or wall segments **27** extending axially along the common axis with adjacent partition walls separated by one of a plurality of slots or openings **28** and a terminal lug **29** extending radially from the second ring **23**. The first ring **22** is positioned in an annular groove **30** formed in the first end **11a** and the walls **24** extend through the body **11** to a circular recess **31** formed in the second end **11b**. Each of the walls **24** is aligned with an associated one of the walls **27** in a pair to form a gap **32** therebetween permitting fluid flow between the walls from the groove **30** to the recess **31**. The gaps **32** are arcuate in shape and correspond in number to the number of pairs of walls. Since the lubricating fluid can become electrically conductive through additives that have metallic components and/or combustion debris from engine operation, the surfaces of the rings **22** and **23** exposed to the lubricating fluid can be covered with a suitable non-conductive material, **22a** and **23a** respectively, to prevent shorting of the capacitor plates. The non-conductive material, **22a** and **23a** can be, for example, a powder coat material. Typical powder coat materials are polyester, epoxy, urethane, and mixtures thereof depending upon the desired characteristics.

Preferably, the first and second rings **22** and **23** each include three of the wall segments **24** and **27** respectively. However, more or less segments can be provided. One of the slots **27** is aligned with the terminal lug **29** so that the terminal lug **26** can extend upwardly through that slot when the rings **22** and **23** are inserted into the body **11**.

A first terminal **33** extends radially into the sensor body **11** and is threaded into the terminal lug **26** for electrical connection to the first ring **22**. Similarly, a second terminal **34** extends radially into the sensor body **11** and is threaded into the terminal lug **29** for electrical connection to the second ring **23**. Each of the terminals **33** and **34** is sealed at the exterior of the body **11** by an associated O-ring **35** for maintaining a seal against leakage either into or out of the body.

In a second preferred embodiment sensing device **10'**, shown in Figs. 4A, 4B, 5 and 6, both the first and second rings **22'** and **23'** include a substantially continuous wall extending axially along the common axis as shown in FIG. 6. The first ring **22'** has a wall **24'** interrupted by a single slot **25'** adjacent to a terminal lug **26'**. The second ring **23'** has a wall **27'** interrupted by a single slot **28'** adjacent to a terminal lug **29'** for

receiving the terminal adapter **26'**. Both of the walls **24'** and **27'** extend only a portion of the axial length into the sensor body **11**. As shown in Fig. 4B, the wall **24'** terminates short of the bottom surface of the recess **31** and the wall **27'** terminates short of the bottom surface of the groove **30**. Otherwise the body **11'** could not be formed as an integral one-piece molded structure. The surfaces of the rings **22'** and **23'** exposed to the lubricating fluid can be covered with a suitable non-conductive material, **22a'** and **23a'** respectively, to prevent shorting of the capacitor plates.

The engine lubricant filtration circuit **16** provides lubricant to the filtration device **14** via the aeration sensing device **10** (**10'**) for filtering contaminants from the lubrication. The lubricant is forced under pressure through the arcuate flow passages or gaps **32** (**32'**) to the filtration device **14**. The aeration sensing device **10** (**10'**) is included in an aeration sensing system **40** (shown in Fig. 6) in accordance with the present invention. A signal generator, such as an oscillator **41**, has an output electrically connected to the sensor second terminal **34** and generates an input signal (e.g. oscillating voltage of fixed amplitude and frequency). The sensor first terminal **33** and the sensor second terminal **34** are connected at opposite ends of a first leg of a bridge circuit **42**. The first leg includes an oil aeration capacitor **43** with plates formed by the walls **24** (**24'**) and **27** (**27'**). A second leg of the bridge circuit **42** includes a first resistor **44** connected between the sensor first terminal **33** and a ground terminal **45**. A third leg of the bridge circuit **42** includes a second resistor **46** connected between the ground terminal **45** and a sensor third terminal **47**. A fourth leg of the bridge circuit **42** includes a compensating capacitor **48** connected between the sensor second terminal **34** and the sensor third terminal **47**. The terminals **34** and **45** are the inputs to the bridge circuit **42** and the terminals **33** and **47** are the outputs at which an output signal is generated. A demodulator **49** has a pair of inputs connected to the terminals **33** and **47** and an output **50** at which a sensor output signal is generated.

As the lubricant passes between the walls **24** (**24'**) and **27** (**27'**), the first capacitor **43** will have a capacitance value that is proportional to the areas of the plurality of partition walls (e.g., capacitance plates) and the net dielectric properties of the lubricant and the gap **32** between them. The demodulator **49** receives the output signal from the bridge **42** and converts it to an output signal (e.g., a DC signal) that is proportional to the capacitance value associated with the lubricant flowing through the first capacitor **43**.

Since the lubricant has a known dielectric constant, changes in the capacitance of the first capacitor **43** will be reflected in the signal at the output **50**. However, any detected changes in the capacitance of the first capacitor **43** can be a direct result of either lubricant specifications, contaminants, aeration entrapped in the lubricant, deterioration of the lubricant, fuel dilution, or temperature affects. Since the change in capacitance may be a direct effect from any one of the sources mentioned previously, aeration entrapped in the lubricant cannot be positively identified as the cause of the change in the capacitance. To differentiate whether the change in the capacitance is a direct result of either the aeration or one of the other sources, the second capacitor **48** is added to the system to compensate for changes to the capacitance of the first capacitor **43** caused by sources other than aeration.

As shown in Figs. 1 and 2, a capacitor segment **51** is retained in the body **11** and has an arcuate plate or wall **52** spaced from one of the walls **27**. The segment **51** is provided with a terminal lug **53** extending radially from the wall **52** and electrically connected to the third terminal **47**. The wall **52** can be made of copper and cooperates with the adjacent wall **27** to form the plate of the second capacitor **48**. A gap between the walls **27** and **52** forms a chamber for receiving the lubricant open to the recess **31** at one end and closed by the body **11** at the opposite end to function as a dead-end cavity. The distance between the capacitance plates and the surface area of the capacitance plates of the second capacitor **48** defines a capacitance equal to the capacitance of the first capacitor **43** when non-aerated lubricant is present in each capacitor. The surfaces of the capacitor segment **51** exposed to the lubricating fluid can be coated with a non-conductive material **52a** in the manner described above.

The arc shaped chamber **54** is arranged so that the lubricant within the dead end cavity is in a substantially stagnant area (i.e., no flow in or out). The dead-end cavity is arranged to be filled with lubricant from the main flow, however, the dead-end cavity will hold the lubricant for a sufficient duration to allow the lubricant to de-aerate. During installation of the sensor **10 (10')**, the chamber **54** is radially positioned at the lowest point by rotating the body **11 (11')** about the conduit **18** so that the ends of the arc are the highest points and any gas entrapped within this chamber can easily escape to the recess **31**. As a result, any difference between the capacitance of the first capacitor **43**

and the capacitance of the second capacitor **48** is due to aeration of the lubricant flowing through the first capacitor **43**.

The resistors **44** and **46** are of equal value and the bridge **42** is balanced when the capacitance values of the first capacitor **43** and second capacitor **48** are equal. Thus, the terminals **33** and **47** will be at equal potential and there is no output signal for the demodulator **49** to sense. When the capacitance of the first capacitor **43** changes due to aeration of the lubricant, the bridge **42** becomes unbalanced and a bridge output signal is generated to the demodulator **49**. If the dielectric constant of the lubricant changes due to some factor other than aeration, the first capacitor **43** and the second capacitor **48** will change capacitance by an equal amount and the bridge **42** will stay balanced. The first capacitor **43** and the second capacitor **48** cause the sensing device **10 (10')** to stay in calibration even though the dielectric constant of the lubricating fluid changes during operation. Furthermore, the bridge **42** has a better immunity to the electrical noise generated by an operating vehicle.

In accordance with the provisions of the patent statutes, the present invention has been described in what is considered to represent its preferred embodiment. However, it should be noted that the invention can be practiced otherwise than as specifically illustrated and described without departing from its spirit or scope.